MARTIAN ENVIRONMENTAL EFFECTS ON SOLAR CELLS
AND SOLAR CELL COVER GLASSES

Contract No. 952582

TTU Report 3301- 2nd Quarterly

15 January 1970

Prepared by
F. Alton Wade
Principal Investigator

Texas Tech University
Department of Geosciences
Lubbock, Texas 79409

MARTIAN ENVIRONMENTAL EFFECTS ON SOLAR CELLS AND SOLAR CELL COVER GLASSES

Contract No.952582

TTU Report 3101- 2nd Quarterly
15 January 1970

Prepared by
F. Alton Wade
Principal Investigator

Texas Tech University
Department of Geosciences
Lubbock, Texas 79409

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, as sponsored by the National Aeronautics and Space Administration under Contract NAS7-100

Technical Content Statement

This report contains information prepared by Texas Tech University under JPL subcontract. Its content is not necessarily endorsed by the Jet Propulsion Laboratory, California Institute of Technology, or the National Aeronautics and Space Administration.

Abstract

This report presents the progress to date of the work on the project entitled Martian Environmental Effects on Solar Cells and Solar Cell Cover Glasses by the Department of Geosciences, Texas Tech University for the Jet Propulsion Laboratory, Pasadena, California, under Contract 952582, a subcontract of NASA, NAS7-100.

The possibility of dust storms on Mars is recognized as is the possibility of detrimental effects of dust storms to any solar cell array placed at or near the surface of Mars. Solar cells will be subjected to dust storms in wind tunnels where simulated Martian environmental conditions prevail. The electrical performance of the solar cells will be tested before and after each test and the damage to the cells will be assessed. A description of the wind tunnel in which experiments at ambient temperatures are performed is presented. As only preliminary tests have been completed, no conclusions or recommendations are presented.

Summary

Various investigators have suggested that dust storms do occur in the rarefied atmosphere of Mars. Because the possibility does exist, it is necessary that the effects of such storms on the performance of solar cells be determined prior to a soft landing on Mars. During dust storms fine particulate matter could be deposited on the cells and the cover glasses could be abraided. In either case the efficiency of the solar cells would be reduced. In order to determine how extensive the damage and blanketing effect to the cover glasses might be and the resulting reduction in their efficiency a series of experiments under predicted Martian environmental conditions has been specified.

A wind tunnel of the "race track" type has been constructed of plastic and will be used in all tests at ambient temperatures.

A second wind tunnel is being constructed of sheet metal. Heating and cooling elements will be provided in order to control the temperature. One series of tests will be run at 245^{o}K and a second series with temperatures reproducing diurnal variations over test periods of up to three days.

Following each test the total transmission of the solar cell cover glasses will be determined and each cover glass will be subjected to microscopic examinations to determine the extent of damage. Current voltage curves will be made before and after exposure to each test in order to evaluate

the effects upon the electrical performance of the solar cells. Cell assemblages will be tested in groups of four with each subgroup having different protective cover glasses, namely, quartz, Corning No. 0211 Microsheet, sapphire and integral.

Preliminary tests with cover glasses of quartz, Corning No. 0211 Microsheet and sapphire indicate that there will be little or no abrasive damage but that a coating of fine particulate matter will accumulate and thus reduce the electrical performance of the solar cells.

CONTENTS

ILLUSTRATIONS

Introduction

Most observers of Martian atmospheric phenomena accept the suggestion that the yellow clouds are dust clouds. Because no reasonable alternative suggestions have been offered, we must accept the possibility that dust storms do occur in the Martian atmosphere (see comments in Technical Discussion section). The effects of wind driven dust and sand particles on equipment to be landed on the Martian surface must be determined. If such effects are detrimental to the operation of the equipment, changes to eliminate these effects must be incorporated in their design.

At present most items of equipment which are flown in space or landed on an extraterrestrial body receive their power from solar cell assemblages. In space or on the lunar surface there are no dust storms so the problem of their detrimental effect has not existed to date. On Mars the problem may exist and equipment may become inoperative for lack of power following a dust storm.

In order to determine the effect of dust storms on solar cells and solar cell cover glasses a series of tests has been designed in which these objects will be subjected to dust storms at specified wind velocities, temperatures or temperature ranges, in a carbon dioxide atmosphere containing a trace of moisture. These tests will be carried out in wind tunnels designed specifically for them. To assess the results the following tests will be made.

(i) The total transmission of the solar cell cover glasses before and after subjecting them to dust storms.

(ii) Microscopy of solar cell cover glasses using phase contrast and polarized light techniques.

(iii) Current voltage curves will be made before and after exposure to dust storms as is necessary to evaluate the effects upon the electrical performance of the solar cell cover glass combinations.

(iv) Following (iii) cover glasses will be removed and the measurements repeated.

Technical Discussion

Based upon data presented in JPL Document No.606-1, dated July 15, 1968 (1), the Martian environment at or very near the surface is as follows.

Surface pressure - ∿10mb
Composition of the atmosphere - >50% CO_2, the remainder probably an inert gas such as argon, plus or minus trace of water vapor.
Temperatures
Maximum at equator - ∿305°K
Minimum at equator - ∿170°K
Mean amplitude of diurnal variation at equator - ∿96°K
Mean polar cap region (estimated)
Winter - ∿220°K
Summer - ∿265°K

The surface material is believed to resemble olivine basalt or tholeiitic basalt. The surface layer is probably composed of unsorted particulate basalt which ranges in size from a few microns to blocks measuring tens of centimeters in dimensions.

Wind velocities based upon observed motions of yellow clouds may range up to 100 km per hour.

In the design of the tests to which solar cells and solar cell cover glasses will be subjected some exceptions to the above specifications were made. Pressure. Because of the extreme difficulty in maintaining a pressure of 10 mb and wind velocities of up to 100 km/hr in a wind tunnel, it was agreed to use ambient pressures. Actually this will result in "worst case" phenomena during tests. Corrected wind velocities can be determined mathematically. Atmosphere. The atmosphere will be 100% carbon dioxide ± a trace of water.

Temperature. One series of tests will be run at ambient temperatures, a second series at 245°K and a third with a diurnal variation from 210°K to 305°K.

Wind Velocities. One series of tests will be conducted with wind velocity at 50 km/hr, a second at 75 km/hr, and a third at 100 km/hr.

Particulate Matter. The dust particles to be used in the tests were obtained by grinding and sieving olivine basalt which was collected in the Hudson Mountains, Ellsworth Land, Antarctica. The principal constituents are clinopyroxene, plagioclase and olivine. A small amount of glass is present. This differs somewhat from the composition of the fines in the lunar soil obtained by the astronauts of Apollo 11. In the lunar material glass constitutes about 50 percent and ilmenite is a principal constituent (2). These compositional differences should not alter the results of the tests significantly. Wind tunnel tests have shown that movement of particles of less than 60 microns in size will not be initiated by wind velocities of 100 km/hr or less. The presence of slightly larger particles is necessary to initiate movement. These larger particles move by the process of saltation and with every bounce finer particles are knocked into the air stream where they remain in suspension. The fines in the lunar soil material brought to earth by the astronauts in the "bulk box" were composed of approximately 45% in the 125-62.5 micron range and 25% in the less than 62.5 micron range (2). Based upon observations of the generation of dust storms in the wind tunnel using various size particles, it was decided that "worst case" conditions could be obtained using a mixture of particulate matter composed of 75% in the 125-250 micron range and 25% in the <62.5 micron range. These are weight percentages.

The schedule of tests is shown in Figure 1.

After many delays the instruments to be used in the current-voltage tests have been assembled and calibrated.

Ambient temperature tests will be begun on January 19, 1970, and will be performed in Tunnel No. 1. It is anticipated that these tests will be concluded in one month. All other tests will be performed in Tunnel No. 2 which will be ready for use on or about February 1, 1970.

Attention is directed to the recent article by Plummer and Carson (3) in which it is proposed that the reddish color of Mars might be due to carbon suboxide and that a possible fast production of this oxide could account for the yellow clouds which have been identified as dust storms. If this is so, corrosive action of the suboxide and related compounds may become an important factor.

Days	Vel. Km	Atmos. CO_2	TEMPERATURES																							
			AMBIENT								AVERAGE (245°K)								DIURNAL CYCLE							
			SOLAR CELL PROTECTION								SOLAR CELL PROTECTION								SOLAR CELL PROTECTION							
			Corning #0211 Micro-sheet		Quartz		Sapphire		Integral Glass Covers		Corning #0211 Micro-sheet		Quartz		Sapphire		Integral Glass Covers		Corning #0211 Micro-sheet		Quartz		Sapphire		Integral Glass Covers	
			A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1	50	Dry																								
		Wet							X	X							X	X							X	X
	75	Dry																								
		Wet	X	X							X	X							X	X						
	100	Dry																								
		Wet			X	X	X	X					X	X	X	X					X	X	X	X		
3	50	Dry																								
		Wet							X	X							X	X							X	X
	75	Dry																								
		Wet	X	X							X	X							X	X						
	100	Dry																								
		Wet			X	X	X	X					X	X	X	X					X	X	X	X		

Figure 1. Schedule of Tests

A = Expanded silver mesh
B = JPL bus bar Dwg #10016709-1
X = First priority experiments

Results of Preliminary Tests

Preliminary tests have been made in the wind tunnel to determine qualitatively the effects of abrasive action on three types of cover glasses, namely, quartz, sapphire and Corning 0211 Microsheet; the results were as follows

a) no abrasive action on any sapphire plate was noted.

b) no abrasive action on any Corning 0211 Microsheet was noted.

c) the quartz plate exhibited minor abrasive damage after three days at 100 KMH

d) all plates were quickly coated with dust immediately after the initiation of the test runs.

These tests indicate that abrasion of the cover glasses will be negligible but that the coating of the cover glasses by the fine particles will be considerable.

References

1. Mars Scientific Model. JPL Document No.606-1. July 15, 1968. Prepared by members of the Lunar and Planetary section.

2. Preliminary Examination of Lunar Samples from Apollo 11. 1969. Science, Vol. 165, p. 1219. Prepared by the Lunar Sample Preliminary Examination Team.

3. Plummer, W.T. and R.K. Carson. 1969. Mars: is the surface colored by carbon suboxide? Science. 166, pp 1141-2.

Appendix

Description of Wind Tunnel No. 1.

The wind tunnel for test experiments at ambient temperatures and preliminary tests is constructed mainly of quarter inch plexiglass. It is essentially a closed system shaped like a race track (Figure 2). The 'atmosphere' is circulated with a squirrel cage blower which is driven by an electric motor. Wind velocities in the straight-away sections of the race track where the tests are performed are controlled by varying the cross section.

Three pairs of straight-away sections are available. With one pair a wind velocity of 50 km/hr is maintained; with the second 75 km/hr and 100 km/hr with the third. With this arrangement no variations in blower rpm are necessary to produce the desired velocities. The solar cell modules to be tested are mounted on weighted brackets in such a way that the entire outer face of each cell and the wire connectors are exposed to the dust storms. Before reassembling the race track an adequate amount of 'Martian dust' is distributed in the various sections. Prior to each test the atmosphere in the race track is swept out and replaced with CO_2 gas in which there is a trace of water vapor. The reason for the use of plexiglass in the race track is to make possible direct view of the dust storms. Preliminary tests have shown that some turbulence is generated in the curved sections, but that the flow in the straight sections when the tests are performed is essentially laminar.

Wind Tunnel No. 2.

The second wind tunnel is the same in design as No. 1, but is constructed of aluminum sheeting and is equipped with cooling devices. The temperature can be controlled. It has the same aerodynamic characteristics as the plexiglass tunnel.

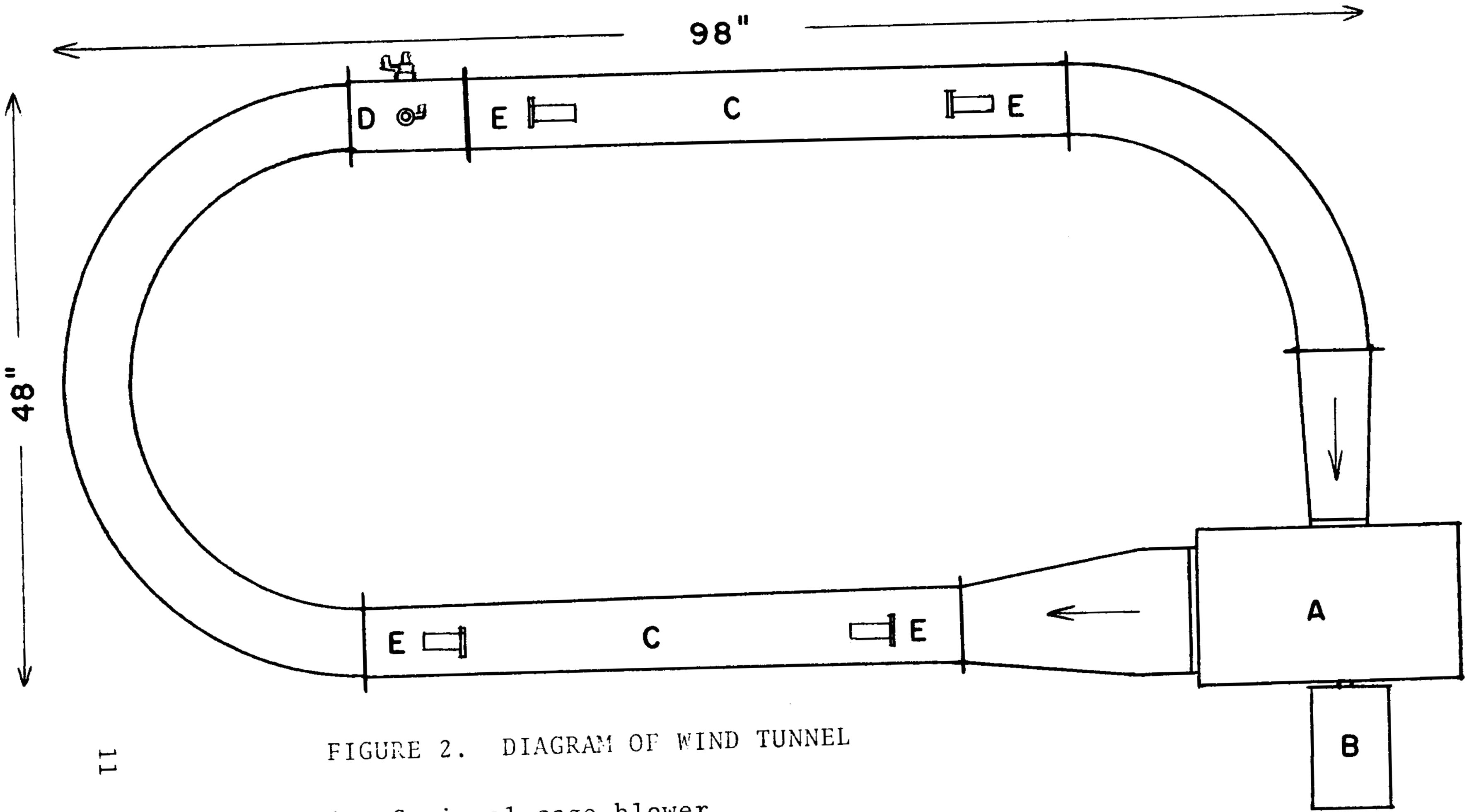

FIGURE 2. DIAGRAM OF WIND TUNNEL

A. Squirrel cage blower
B. Motor
C. Removable straight-away sections
D. Valve section. CO_2 inlet and outlet
E. Solar cell assemblages